COASTAL AEROSOL CHARACTERIZATION

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LONG-TERM GOALS

The long term goal is to understand all the aerosol source, sink, and transformation processes, both physical and chemical, which are important in determining the dynamical evolution of the aerosol size distribution. The results of this understanding are formulated in terms of a process-oriented aerosol model which will eventually be combined with meteorological models to predict the aerosol size distribution in 3-D regional models. The predictive model can be used, not only for research purposes, but as a foundation for a model to predict the effects of aerosols on DOD EO systems.

OBJECTIVES

Develop a process-oriented model which includes all the source, sinks, transformation and transport processes necessary to describe the evolution of the aerosol size distribution in the marine and coastal atmospheric boundary layer. Test the model to see if it adequately describes the individual processes. Study the sensitivity of the model predictions to uncertainties in initial conditions and key rate-controlling parameters. Investigate the time scales and relative importance of the different processes under various meteorological conditions. Take the first steps of integrating the model with a meteorological model, i.e. integration of aerosol dynamics with MBL model. Validate the model with existing data sets.

APPROACH

Start with the prior one dimensional (box) sectional model developed by NRL which had rigorous treatment of coagulation, surface deposition, growth by condensation of gas-phase reaction products, surface source of sea-salt aerosol, and precipitation scavenging, and add vertical structure (mixing and humidity gradients). Use this model to investigate time scales of various processes, interactions of time scales, and stiffness due to differing time scales. Test various processes against analytical solutions where possible. Once this 1-D model has been tested, combine it with 1-D MBL model to provide real-time mixing coefficients, and temperature, humidity, and wind soundings. Eventually, with the experience gained from the above, aerosol processes will be integrated with a 3-D meteorology model

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which will supply real-time input data required by the aerosol processes and transport.

WORK COMPLETED

The 1-D model is now fully developed and has been used to study the time scales and relative importance of various aerosol processes under a variety of meteorological conditions. Three papers on this modeling effort have been submitted for publication and are referenced below. The first paper describes the model and all the source, sink, transformation and transport processes included in the model. The second paper presents several applications of the model, including a study of the evolution of the MBL aerosol size distribution in air masses advecting off the east coast of the U.S., and a study of the possible self-initialization of the model for the case of the remote ocean. The third paper describes advances in numerical techniques developed specifically for this paper.

RESULTS

Simulations of MBL aerosol dynamics with the 1-D aerosol model have revealed the following:

(1) The transformation of the continental aerosol size distribution into a remote marine-type distribution during advection over the ocean occurs on a time scale of 6 to 8 days.

(2) The time scales for the growth of cloud condensation nuclei (CCN) due to sulfate formation in cloud droplets and for turbulent mixing throughout in the MBL are much faster than typical "filling time" of the MBL due to exchange with the free troposphere (FT). Therefore, the effect of cloud processing of aerosols (i.e., formation of a double-peaked size distribution) will be observed throughout the MBL, even at the surface, whenever nonprecipitating clouds are present. Since the time constant for filling due to FT exchange is about two days for a typical exchange velocity of 0.6 cm per s, the cloud processing minimum in the size distribution will tend to fill in after several days with no clouds.

(3) Exchange with the FT can be a significant source of particles (CCN) in the size range defined by the cloud processing minimum. However, there may be a flux of particles out of the MBL at sizes comprising the cloud residue mode.

(4) Long-term (eight to ten day) predictions of marine aerosol size distributions were found to be essentially independent of initial conditions. Thus, the model can be self- initialized for the prediction of aerosol size distributions in air that has been over the ocean for ten days or longer. However, the results also show that while self-initialization is possible, the effect of MBL aerosol is more dependent on the FT aerosol than previously realized. Therefore uncertainties in the FT aerosol size distribution propagates downward into the MBL and becomes the major source of uncertainty over remote oceanic regions.

(5) For a typical exchange velocity of 0.6 cm per s, the Aitken mode (peak at about 0.035 microns radius) of remote marine size distributions will be maintained by exchange with the FT since particles in this size range will be supplied faster than they are removed by coagulation and condensation. In this case, the concentration of Aitken particles in the MBL will be nearly in balance with the FT.

IMPACT

The modeling work supported by the PRIMER has produced a process-oriented aerosol model that is state-of-the-art in terms of the description of aerosol physics and chemistry, in terms of the correct treatment of the coupling between vertical transport and aerosol growth and in terms of the incorporation of new numerical algorithms which significantly improve the accuracy with which the processes of dynamic condensation, cloud processing and gravitational settling are modeled.

TRANSITIONS

The model has been designed in a format which is suitable for later integration with a local or mesoscale meteorological model. The addition of MBL aerosol prediction to Navy meteorological models will make it possible to evaluate and predict the effects of aerosols on EO propagation which is required to predict performance of EO systems under different meteorological conditions. Incorporation of this 1-D aerosol model into a mesoscale model is in the planning stage.

RELATED PROJECTS

The work reported here built on the earlier joint effort of Dr. Fred Gelbard at Sandia National Lab. working under support of an ONR contract in FY93 and 94, and NRL, Code 7228 (Dr. J. Fitzgerald).

A new NRL FY97 ARI, Coastal Aerosol Processes, is devoted to improving the understanding of aerosol processes and developing improved mathematical formulation of these processes. As these improved formulations are developed, these improvements will be added to the model being developed here.

Navy 6.2. P.E.0602435N, Project DN302215 is a program at NRaD which developed the NAM and NOVAM aerosol models as a TDA and has ongoing programs to improve and validate them. The P.I.s are working actively with the P.I. of this 6.2 program to improve the existing data-based model and supply more advanced models in the future.

SPAWARS: P.E. 0603207N Project X2008 is a project to validate and transition electro-optical tactical decision aids (EOTDAs) for special requirements. A major part of this project is to develop EOTDAs which predict the effect of aerosols on E-O systems.

Others: National climate change program. There has been a significant increase in aerosol research driven by a number of programs sponsored by DOE, NASA, and NOAA. The results of ONR/NRL's program has not gone unnoticed by the climate change community. The underlying physics, chemistry, and optics necessary to understand and assess the effects of aerosols on global radiative problems are the same as those required to assess and predict the extinction of E-O signals between a target and a detector. Both applications require the characterization of the aerosol size

distribution and composition in a three dimensional atmosphere. The primary difference is in the scales of interest. Navy applications require spatial resolution on the local and regional scale, while climate modeling requires global characterization. It is clear however, that the small scale processes drive the larger scale phenomena, and are necessary for any predictive model of climate change. For climate change prediction the national program recognizes a need for process-oriented models (in addition to global aerosol data) for evaluating the effect of different policy scenarios.

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